(Griffith)

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CHEMISTRY

OF THE

FOUR ANCIENT ELEMENTS,

FIRE, AIR, EARTH, AND WATER:

An Essay

FOUNDED UPON LECTURES DELIVERED BEFORE HER MOST GRACIOUS MAJESTY

THE QUEEN.

BY

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TO

HER MOST GRACIOUS MAJESTY

THE QUEEN,

BY SPECIAL PERMISSION,

This Essay

ON

THE CHEMISTRY

OF

THE FOUR ANCIENT ELEMENTS,

FOUNDED UPON LECTURES DELIVERED BEFORE

HER MAJESTY,

IS DEDICATED

WITH SENTIMENTS OF PROFOUND GRATITUDE

AND FERVENT LOYALTY,

BY HER MAJESTY'S MOST HUMBLE

AND DEVOTED SERVANT,

THOMAS GRIFFITHS.

ADVERTISEMENT

TO THE FIRST EDITION.

THIS Essay on the Chemistry of the Four Ancient Elements is chiefly intended for those who have not studied the Science.

Abstruse details and theories are therefore avoided, useful and interesting information supplied, and instruction united with entertainment.

Explicit directions are given respecting the performance of the Experiments, and cautions concerning the nature of several agents employed during the inquiry will be found in the Appendix.

ADVERTISEMENT

TO THE SECOND EDITION.

THE first Edition of 'The Chemistry of the Four Ancient Elements' was out of print a few months after its publication: encouraged, therefore, by the reception that it met at the hands of the Public, and by the favourable notices of the Press, I have now put forth a Second Edition, and trust that it will be found to merit the success of its predecessor.

I take this opportunity of stating, that in the construction and arrangement of the models and apparatus, and in the experiments during the Lectures, as delivered before the Queen, I had the valuable assistance of my brother, Mr. William Griffiths, of Kensington.

T. G.

February, 1851.

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INTRODUCTORY.

A DARK and mysterious art, called Alchemy, which originated with the Arabian sages about the seventh century, was the parent of the brilliant and enchanting science of Chemistry.

Philosophers of the polemical schools maintained that Fire, Air, Earth, and Water, were the Four Elements of Nature; but the disciples of Alchemy denied the validity of this doctrine, and asserted that Salt, Sulphur, and Mercury, were the Three Elements, from whose admixture or union emanated the various productions of the animal, vegetable, and mineral kingdoms.

Both notions were erroneous, as the sequel will prove, but that of the alchemists rapidly excited intense interest, because it led to the performance of curious experiments, and to the observance of strange phenomena attendant upon the mixture of acids, salts, spirits, and metals.

Thus, under the auspices of the alchemists, metals were changed into gold, and base metals assumed the colours and forms of precious stones, and suddenly reappeared in their original forms.

These and other unexpected and apparently magical results were well calculated to arouse the curiosity and astonishment of the operators, who, finding themselves gifted with the power of eliciting such marvels, easily imagined that they could actually create substances, or transmute them into each other.

Avarice immediately prompted the most ardent exertions to be made to change worthless lead into precious gold, and held forth the inviting hope, that the mere alteration of the quantity of Salt, Sulphur, and Mercury of the one metal would cause its Transmutation into the other.

The alchemists, therefore, constructed powerful furnaces, invented curious stills, alembics retorts, crucibles, and much costly and complicated apparatus for extracting strong acid salts, and solvents, from minerals and earths.

Aided by these they commenced an arduous search throughout all Nature, for an imaginar

substance, which they named the Philosopher's stone; a minute fragment of this miracle of art, when discovered, and thrown upon molten lead, was destined to alter the proportions of its three supposed elements, to cleanse it from impurity and dross, and transmute it into pure and effulgent gold.

From the laboratories of Arabia, the principles of this seductive art soon spread over Europe, and all ranks of society joined in wild pursuit of the golden phantom for a long succession of ages; vain was their incessant toil and labour, it eluded their anxious grasp, and instead of enjoying riches and splendour, they invariably languished in poverty and misery.

The alchemists, baffled in the acquisition of metallic treasure, sought after a powerful liquid for dissolving all things; but this was quickly abandoned, because an Universal solvent could not be retained in their retorts or crucibles.

Ultimately they dared to think Immortality within their reach, and presumptuously endeavoured to prepare a medicine to prevent the decay of nature, and prolong life to an indefinite extent; but disease and death were the grim attendants upon the operators, who trusted to

obtain an Elixir of life amidst the poisonous fumes of the furnace.

Such were the three grand objects of alchemic art, and though abortive in regard to their anticipated results, yet productive of the good effect of inducing philosophers to descend from disputes upon words, to experiments upon things.

Accordingly, out of the vast mass of intricate materials accumulated by the alchemists, a few master minds were enabled to select, examine, and classify valuable facts, striking experiments, and wonderful phenomena, which had been either abandoned or forgotten during the infatuated pursuits now briefly described.

The gradual introduction of metallic preparations into Medicine, as substitutes for the drugs and simples of its ancient practice, and of others into the arts and manufactures, conjoined with the publication of essays concerning these and other experimental facts, eventually drew the attention of civilized society to the utility of the labours of the philosophers, who engaged upon the ruins of the once dearly cherished, yet delusive art, and in an incredibly short time, like the fabled Phœnix of Arabia, Chemistry soared from the ashes of Alchemy.

Chemistry, guided by accurate experiment and sound theory, has attained its just rank in the circle of the sciences, and has proved the intimate connexion of its beautiful facts and doctrines, with the wonderful phenomena of the world, and their great utility when judiciously applied to the arts of life, in aid of the wants, comforts, and luxuries of mankind.

The votary of Chemistry is not chained to the flaming furnace in fruitless labour after gold, nor compelled to invoke witchcraft and magic for the production of an universal solvent, nor immured in the dark laboratory, amidst deadly exhalations, to discover the art of prolonging life; no! in this happy age, the fetters of ignorance and superstition are shattered by the powerful hand of Truth, and he comes forth with freedom into the glowing sunlight of Philosophy, as the servant and interpreter of Nature; he looks abroad into the rich and magnificent Universe, calls the delightful scenery all his own, the mountains, the valleys, the oceans, the rivers, and the sky; through these wide bounds he is free at will to choose

> Whate'er bright spoils the florid earth contains,
> Whate'er the waters, or the ambient air.

All present him with perfect instances of the consummate wisdom of the Almighty God, who created a World so fraught with beauty, and by their examination he gains materials for reflection and research, which, if properly applied and pursued, not only enlighten and adorn, but exalt and purify his mind, teaching him to appreciate the miraculous workings of an Omnipotent and Eternal Power.

Chemistry is the most instructive and delightful study that can be pursued, because it is purely a science of Experiment; no anticipation can be formed as to the results which will ensue upon the presentation of different substances to each other.

By making experiments with great attention and accuracy, and intently studying the results, philosophers soon discovered the real nature of the Four Ancient, and the Three Alchemical Elements; a short account of the conclusions which are thus established will furnish a correct notion of the modern meaning of the term Elements, which will frequently occur during the present inquiry.

Fire is not a peculiar or distinct principle, but a result of intense attraction between two

or more substances. Air is a mixture of two gases, called Oxygen and Nitrogen. Earth is a compound of Oxygen and numerous Metals. Water is a compound of Oxygen and a gas called Hydrogen.

Salt is a compound of a vapour called Chlorine, and a metal called Sodium; but the components of Sulphur and Mercury are unknown, therefore these two substances are called Elements, to denote that they have not been analysed, and in this acceptation of the term Oxygen, Nitrogen, Hydrogen, Metals, and several other substances, are Elements; altogether there are Fifty-six such Elements: their names are shown in the following list.

MODERN ELEMENTS,

AND DERIVATION OF THEIR NAMES.

ALUMINUM. A metal thus named from the Latin *alumen, clay.*

ANTIMONY. A metal thus named from the Greek ἀντι, *against,* and μονος, *monk,* because several monks were poisoned by its preparations.

ARSENIC. A metal thus named from the Greek ἀρσενικον, *powerful*, on account of its strength as a poison.

BARIUM. A metal extracted from Baryta, a heavy mineral thus named from the Greek, βαρυς, *weight*.

BISMUTH. A metal said to be thus named by the German miners, from *wiessmatte, a blooming meadow*, because of the variegated hues of its tarnish.

BORON. A non-metallic combustible, obtained from Borax, a substance so called from the Arabic, *buruk, brilliant*.

BROMINE. A non-metallic incombustible liquid; its name is derived from the Greek, βρωμος, *stench*, on account of the insupportable odour of its vapour.

CADMIUM. A metal thus named from the Greek καδμεια, *calamine*, an ore of zinc.

CALCIUM. A metal thus named from the Latin *calx, lime*.

CARBON. A non-metallic combustible, thus named from the Latin *carbo, coal*.

CERIUM. A metal thus named in honour of the planet *Ceres*.

CHLORINE. A non-metallic incombustible vapour,

thus called from the Greek χλωρος, *green*, in allusion to its colour.

HROMIUM. A metal thus named from the Greek χρωμα, *colour*, on account of the varied hues which its compounds assume.

OBALT. A metal thus named after *Kobold*, a sprite or gnome of the German mines.

OLUMBIUM. A metal thus named from its discovery in a mineral from *Columbia*.

OPPER. A metal thus named from being originally wrought in *Cyprus*.

IDYMIUM. A metal thus named from διδυμοι, *twins*, on account of its resemblance to Lantanum.

LUORINE. A non-metallic uninflammable vapour, extracted from *fluor-spar*.

LUCINUM. A metal extracted from a mineral named Glucina; a term derived from the Greek γλυκυς, *sweet*, on account of such taste being communicated by its compounds.

OLD. A metal the etymology of whose name is uncertain.

YDROGEN. A non-metallic inflammable gas, and being an element of water, it is thus called from the Greek ὑδωρ, *water*, and γενω, *to generate*.

sume a red colour; hence its name from the Greek ῥοδων, *a rose.*

SELENIUM. A non-metallic inflammable element, thus named in honour of the moon from the Greek σεληνη, *the moon.*

SILICIUM. A metal thus named from the Latin *silex, flint.*

SILVER. A metal, the origin of whose name is obscure.

SODIUM. A metal obtained from the ashes of a plant called the *salsola soda.*

STRONTIUM. A metal extracted from a mineral discovered at *Strontian.*

SULPHUR. A non-metallic combustible, whose name is probably of Arabic extraction.

TELLURIUM. A metal thus named in honour of the Earth, from the Latin *Tellus, the earth.*

THORINUM. A metal thus named in honour of the Saxon deity *Thor.*

TIN. A metal, the origin of whose name is a matter of doubt.

TITANIUM. A metal thus named in honour of the *Titans* of heathen mythology.

TUNGSTENUM. A metal thus named from the Swedish word *tungsten, heavy-stone,* from which it was extracted.

URANIUM. A metal thus named in honour of the planet *Uranus*.

VANADIUM. A metal thus named in honour of *Vanadis*, a Scandinavian deity.

YTTRIUM. A metal extracted from a mineral found at *Ytterby*.

ZINC. A metal supposed to be thus named from the German *zinken*, *nails*.

ZIRCONIUM. A metal obtained from a gem called *zircoon*, by the Cingalese, in allusion to its four-cornered shape.

By far the greater number of the above host of elements have been elicited by chemical analysis; very few are presented absolutely pure by Nature.

The Elements may be thus classed:

I. Forty-four Metals, Aluminum, Antimony, Arsenic, Barium, Bismuth, Cadmium, Calcium, Cerium, Chromium, Cobalt, Columbium, Copper, Didymium, Glucinum, Gold, Iridium, Iron, Lantanum, Lead, Lithium, Magnesium, Manganesium, Mercury, Molybdenum, Nickel, Osmium, Palladium, Platinum, Potassium, Rhodium, Silicium, Silver, Sodium, Strontium, Tellurium, Thorinum, Tin, Titanium, Tungstenum,

Uranium, Vanadium, Yttrium, Zinc, and Z
conium.

II. Three Gases, Hydrogen, Oxygen, a
Nitrogen.

III. Two Vapours, Chlorine and Fluorine.

IV. One Non-metallic fluid, Bromine.

V. Six Non-metallic solids, Boron, Carbo
Iodine, Phosphorus, Selenium, and Sulphur.

The Supporters of combustion are Bromin
Chlorine, Fluorine, Iodine, and Oxygen.

The Combustibles are, Boron, Carbon, Hy
drogen, Phosphorus, Selenium, and Sulphur.

It must be particularly remembered that th
Chemist does not affirm these substances to b
the Atomic, or Absolute Elements of Nature
on the contrary, he deems it extremely probabl
that they may be analysed or decomposed i
the course of time, but until this be effecte
he styles them Elements for convenience o
discussion, and as a confession of the limits o
his analytical skill.

The Chemist investigates the habitudes o
these Elements, discovers how they combine t
form Compounds, and how these combine t
form Double compounds; he ascertains th
Weight in which these Primary and Secondar

combinations ensue, and how the elements of all known compounds may be separated; he determines the laws which preside over all these changes, and studies to apply such knowledge to the interpretation of natural phenomena, and to useful purposes in the arts of life.

Throughout these extensive researches the Chemist depends entirely upon Experiment; and the marvels which it reveals are referrible to the exertion of a power which promotes union between elements and compounds, even though their natures be strongly opposed.

This power is called Chemical Attraction, Attraction of Composition, or Chemical Affinity, the latter term being used in a figurative sense, to suggest the idea of peculiar attachments between different substances, under the influence of which they combine so that their individual characters are totally changed and disguised.

Thus, the Elements Hydrogen and Oxygen, are gases viewless as air, the one combustible, the other incombustible, and they are opposed in other respects, but they have mutual affinity, and combine to form the liquid Compound called Water.

The violent collision of two lumps of an ore now called the Bisulphuret of iron, was also a ancient method of obtaining fire, and hence th ore obtained the name of Pyrites, or Fire-stone from the Greek word πυριτης; it is used at pre sent by the Patagonians.

When two lumps of Pyrites are struck toge ther, brilliant sparks appear, which are littl fragments of the ore abraded by the shock, an so suddenly heated by the friction, as to b enabled to burn or combine with the oxygen o the air; and these sparks falling upon dry com bustible matter, immediately cause it to do th same.

Fire was the grand and idolized agent of th Alchemists; they discovered several methods o summoning it quickly into their presence, bu these were confined to the mystic region o their laboratories, or only exhibited occasionall to astonish the unlearned and uninitiated, wh were obliged to rest content with employing th rude contrivances of their forefathers.

Modern Chemists have numerous method of suddenly eliciting Fire; these are not kep as secrets, but are presented for the convenienc of society, under the popular name of Instan

taneous Lights, which are too well known to require a minute description.

Some of the instantaneous light matches contain the element phosphorus, which, by very slight friction, becomes hot enough to attract the oxygen of the air and burn with flame; others contain complicated compounds, which, by various means, are induced to exert a similar action; and all are so cheap, that there is no difficulty in obtaining Fire, either for chemical or domestic employment.

The Alchemists had a favourite aphorism to the effect that without Fire they could not work; and indeed, so universal is the employment of this agent in the present state of science, that the Chemist is often called "The Philosopher by Fire."

Substances which kindle readily are popularly called combustible; some of them are natural, and others artificial productions, and their burning or combustion is induced and supported by the oxygen of the air, which is called a supporter of combustion, because no ordinary fire or flame can burn without its presence.

There are many natural substances exceed-

ingly combustible, such as wood, straw, flax, &c yet the most intense heat of the sun is no sufficient to kindle them; if it were, dreadfu conflagrations would be constantly taking plac and the labours of the husbandman would b in vain.

This is a fact highly illustrative of the grea wisdom and goodness of the Creator, in pro viding an adjustment so accurate, between th temperature of the sun, and the vegetable pro ductions of the earth, that they may be warme and cherished, but never kindled and consume by its powerful rays.

All natural combustible substances employe as sources of Fire, require the application o artificial heat before they will kindle; and th process of combustion, in all cases, may b defined as the exhibition of intense chemica affinity between the element or elements of th combustible substance, and some supporter o combustion, attended by the evolution of hea and light.

During combustion, no actual destruction o the elements of the combustible takes place; in fact, throughout the whole range of Chemistry there cannot be found an instance of annihila

tion, but new, complex, and frequently invisible compounds are formed, which, when analysed, present their original elements unaltered.

An examination of the phenomena which take place during the burning of a wax candle, will illustrate this matter to a certain extent.

Wax is a white solid substance, consisting of the elements Oxygen, Carbon, and Hydrogen; when fire is applied to the wick of a wax candle, the wax melts or becomes liquid; this changes into vapour, and kindles in consequence of the oxygen of the wax and of the air uniting with the carbon to produce carbonic acid; and the hydrogen uniting with other portions of oxygen from both sources to form water.

These products, as they arise from the flame in a heated state, are quickly diffused through the surrounding air, and escape ordinary detection; and this action continues until the candle is burnt out, or, chemically speaking, converted into carbonic acid and water.

The actual quantity or weight of these products can only be learned by the most refined experiments, but their mere presence can be detected by very simple means.

Let a clean, dry, cold glass tumbler be held

over the flame of the candle for a minute, as shown in fig. 1.

The heated vapour of the water which is evolving will be cooled and condensed like dew on its interior.

Remove the tumbler from over the flame, still with its mouth downwards, which close with a thick card, as shown in fig. 2. This will prevent the invisible carbonic acid from escaping; and now the tumbler may be placed in its usual position on the table, with the card uppermost.

The card may then be drawn a little aside, so that a small quantity of clear lime-water can be poured into the tumbler in the position represented in fig. 3.

Cover the mouth of the tumbler again with the card; hold it firmly, while the tumbler is gently shaken, so as to agitate the lime-water, which will instantly become milk-white, because the lime chemically attracts the invisible carbonic acid which the cold glass could not condense, as it did the vapour of the water, and a compound of carbonic acid, called a Carbonate of lime, is produced.

The Chemist, therefore, regards the cold glass as a test of the presence of the water, and the

ime as a test of the carbonic acid, produced by he burning of the wax candle; and he can, by very refined methods, collect them both, extract the Oxygen, Hydrogen, and Carbon, and prove that the united weight of these three elements equals that which the candle had before it was lighted; he, therefore, infers that no destruction of matter has ensued during the combustion.

The beautiful pointed form of the candle flame is very remarkable, and it depends upon the air rushing around the candle to supply oxygen, becoming heated, and then rapidly ascending and drawing the flame in its track.

The pointed form of flame can be pleasingly exhibited by the following simple experiment. Let a ball of cotton, about the size of a walnut, be suspended from a very fine iron or copper wire, two feet long, then soaked in spirits of wine and lighted, a beautiful flame will be produced, as shown in fig. 4.

If the air were not rushing swiftly upwards to supply this flame, and, therefore, pressing more against the lower than the upper part of the ball; or, in other words, if the air were pressing equally all around, the flame would

not appear thus: it would envelop the ball, and assume a spherical figure; but no flame can burn without disturbing the equilibrium of the air, as will fully appear hereafter.

That the air does rush swiftly upwards and around a flame, and is absolutely necessary for its sustenance, that a flame becomes impaired or extinct by diminishing or preventing the access of air, may be rendered evident by a few simple experiments.

A short piece of wax candle may be lighted and placed upon the table, and a cylindrical lamp-glass held over it at a little distance from the surface of the table, as shown in fig. 5.

The air will now enter from the surface of the table through the lower part of the lamp-glass with freedom, and in quantity sufficient to maintain as bright a flame as the candle would burn with under ordinary circumstances, and thus coming to support the flame, yields its oxygen, to the hydrogen and carbon of the wax, and then escapes at the top of the glass with the products of combustion, namely, watery vapour and carbonic acid, whilst fresh air enters below to perform a similar office; and thus the flame will continue burning with freedom.

Let the top of the lamp-glass be partially covered with a flat metal plate, as represented in fig. 6.

The flame becomes dim, because the air which has yielded oxygen cannot freely escape; and if the top of the lamp-glass be entirely covered, the flame dies, because the air is quite prevented from escape.

The glass remains full of burnt air, that is, of air contaminated with watery vapour and carbonic acid; and though the glass is still open below, no fresh air can enter whilst its interior is thus occupied.

Let the candle be again lighted, and enclosed by the lamp-glass standing on the table, and having its top uncovered, as shown in fig. 7. The flame still burns, though not with freedom, because the burnt air is endeavouring to ascend, and fresh air to descend through the top of the glass; there is a struggle between the ascending and descending air, the flame cannot obtain its due share of the latter, and therefore burns languidly or fitfully.

If the top of the glass be closed, as shown in fig. 8, the flame soon dies for absolute want of air, its own products being unfit for its support.

The following are beautiful experiments illustration of the ascending and descendi currents of burnt and fresh air.

On the centre of a flat and smooth piece marble, wood, or slate, either circular or squa place a bit of common wax candle, one inch lon and light the wick.

Take a glass, resembling in shape that of bottle, the lower part of which is removed; th glass must be four inches in diameter, a seven inches high, and its neck three quarters an inch internal diameter, and one inch lon the mouth or rim of the glass must be grou smooth, and lightly anointed with pomac Place the glass over the lighted candle, so th its rim may stand upon the flat marble, wood, slate, press it slightly, that the surfaces m adhere closely.

The flame will soon languish and die, b cause the burnt air within the glass, and t fresh air without, struggle and neutralize ea other in the narrow neck, and neither c escape nor enter; the form of the experime is shown in fig. 9.

Remove the glass, relight the candle, a place in the neck of the glass a flat piece of t

plate, four inches long, one inch wide at its upper, and half an inch wide at its lower part, so that it may stand exactly in the centre of the neck.

Place the glass over the flame as before, and it will continue burning with the same freedom as in the open air, for by this simple partition the struggle of the ascending and descending currents is prevented, they are furnished with separate paths of exit and entrance; as shown by the arrows in fig. 10.

To detect these currents, let a small green wax taper, fastened to a wire handle, be lighted, and allowed to burn for a minute; then gently blow out its flame, so as to leave the wick smoking; apply the wick on one side of the partition, and if the burnt air be ascending there, the smoke will ascend also; apply it on the other side, and if the fresh air be descending there, the smoke will descend with it. The arrangement is represented in fig. 11 and 12.

Draw out the partition, and the flame will soon cease.

If the flame of a candle be examined, a dull spot will be noticed in its centre immediately above the wick, as shown in fig. 13.

The combustion of the vapour of the wax is

air necessary for the combustion of the vapour of the oil, enters simultaneously through the perforations of the cup to the interior circle, and through those of the gallery to the exterior circle of the wick, and the contraction of the glass causes the air to rush against the flame, to ensure its perfection; the direction of the air is shown by the small darts.

No dark spot will be observed in the properly-regulated flame of the Argand lamp, because all the combustible matter is consumed; the height of the wick is regulated by turning the gallery right or left, for there is a wire connected with it, that passes to a ring at the bottom of the wick, so that it may be elevated or depressed; this is not shown in the engraving, as it would complicate the description.

Whilst the flame is burning with brilliancy, let a cloth be folded around the cup, so as to cover the perforations and prevent the entrance of air to the interior of the flame; it will instantly become dull and smoky, because the air which is yet rushing to its exterior through the perforations of the gallery is insufficient to consume all the vapour produced by the wick; a great portion escapes unburnt as black soot; remove

the cloth and the flame will resume its brilliancy.

The use of the cup is to receive any excess of oil that may drop away from the wick, and if this be not removed when the lamp is trimmed, it will accumulate and stop the perforations, and the flame will burn dull and smoky.

The Argand-gas burner for consuming coal-gas is generally made about the same size as that of the dining-table lamp, and is similar to it in principle, though slightly modified in form to suit the peculiar nature of the combustible substance which, being already gaseous or aeriform, requires no wick; in fig. 18 this contrivance is represented in section.

It consists of two tubes, the one within the other, as already described; below they are united closely by a ring, and above by a ring pierced with twelve or fourteen holes, not larger than will admit a fine sewing needle: a tube at right angles is connected with the lower part of the outer tube, a cylindrical glass, contracted as before, is supported on a perforated gallery attached near the middle of the burner.

The tube at right angles is connected with the gas-pipe of supply, the gas rushes through it

stead of resin the box is filled with a very fine combustible powder, called Lycopodium, from the Greek λύκος, a wolf, and πόδος, a foot; it is the seed of a species of Club moss, which bears some resemblance to the foot or paw of a wolf; lycopodium, shaken through the spirit flame, flashes more instantaneously and vehemently than resin, but entirely consumes, so that the performer is not annoyed by smoke.

In the wax, tallow, or oil employed as sources of light in candles and lamps, the elements Hydrogen, and Carbon, or Charcoal, are combined by some wonderful power of Nature; and the action which ensues when these combustibles are heated so as to produce flame, may be stated as follows:

Hydrogen being the most inflammable element, kindles first, whilst the Carbon with which it was united, is liberated in a most minutely divided solid state throughout the flame, momentarily ignited to whiteness, and then burned; and being thus constantly showered through the flame, great and steady light is emitted.

For all purposes of illumination, it is essential that the light of flames should resemble

sun light, in consisting of the seven primary colours, namely, Red, Orange, Yellow, Green, Blue, Indigo, and Violet; but artificial light is seldom perfect in this respect, and accordingly candlelight is unsuited for the true display of colours, it generally containing excess of yellow rays.

A most curious effect may be produced by illuminating an apartment with yellow light, which can be commanded as follows; let a tin dish, twelve inches diameter, and half an inch deep, be supported on a tripod over a spirit-lamp, as shown in fig. 21. Pour into the dish two fluid ounces of spirits of wine, and one ounce of water; kindle the flame of the lamp, and darken the apartment: then hold a lighted slip of paper, so as to kindle the vapour of the heated spirits in the dish, and throw into it at the same time a handful of common salt, and stir it with a thick iron wire.

Yellow light is abundantly evolved, and it will show no objects in the apartment of their proper colours, excepting such as can reflect yellow light; the most brilliant red and blue drapery, flowers, &c., appear dingy, or black, the countenances of all in the apartment assume a

livid ghastly hue; but if in this state of things a handful of Lycopodium be thrown into the flame, its combustion emits white light, and at the instant of the flash every object appears of its true colours.

Flame requires great heat for its existence; and although spirits of wine, turpentine, and ether are popularly [illegible] exceedingly inflammable substances, they [illegible]ll not burn until heated to whiteness; eth[illegible]s the best that can be employed to prove [illegible]ct, in the following manner:

Take a fine platin[illegible]e, about the size of that at page 37, and [illegible]teen inches long; coil it around a cedar d[illegible]ving pencil, so that upon removal it will fo[illegible] piral, as represented in fig. 22; let a teaspoonful of ether be poured into a tall ale-glass, and in the course of a minute it will become filled with the vapour of that volatile liquid.

Hold the straight end of the platinum wire, so that the flame of a spirit-lamp may heat the spiral red-hot; then remove it, and quickly plunge it into the glass, so as nearly to touch the ether, as represented in fig. 23.

The spiral will continue glowing red-hot, but

the vapour of the ether will not inflame until, as often happens, the spiral increases its heat to whiteness; so long as it remains merely red-hot, the ether is induced slowly to change its characters, and exert affinity for the oxygen of the air; in fact, it is consuming without flame; but when the spiral becomes fairly white hot, the affinity of the ethereal elements for the oxygen is hurried, and the ether burns with a luminous flame. This beautiful experiment proves that flame requires great heat for its existence: and one very familiar example of the fact may be here adduced.

Let the wick of a candle be lighted, and the flame allowed to burn until the wick is nearly as high as the flame; then let it be blown out, and although the wick remains red-hot and glowing, it is not sufficiently hot to inflame the vapour of the wax or tallow which is yet rising like a smoke.

Let a slip of lighted paper be held in the ascending vapour, about one inch from the top of the wick; it will instantly inflame, by the white heat of the burning paper, and suddenly flash down to the glowing wick, so that it is rekindled, and combustion proceeds as usual.

coal-gas, which mixes with the air in the box, and forms an explosive medium, the flame enlarges, and is then extinguished, the cage being filled with a flickering lambent blue light, due to the combustion of the imprisoned gas, which cannot escape as flame to kindle the surrounding mixture.

Upon turning off the supply of gas, the wick of the lamp rekindles; upon re-admitting it, the appearances again ensue, and if a lighted taper be introduced into the box, an explosion takes place.

If coal-gas cannot be procured, the air in the box may be rendered explosive by the introduction of a tablespoonful of ether, the lamp will burn in it with safety; but an unprotected flame will cause an explosion.

In all these experiments upon the temperature of flame, the heat is carried away by the metal of the wire gauze; and in chemical language all metals are said to conduct heat; thus, if one end of a bar of metal, such as the steel poker, be placed in the fire, and the other held in the hand, the heat gradually travels from one end to the other, and the hand cannot endure it after some time; this is a familiar example of

the conducting power of metal; and the progress of the heat throughout a metallic bar may be strikingly illustrated by the simple arrangement shown in fig. 27.

It represents a bar of iron, eighteen inches long, and three quarters of an inch square, supported at its centre upon a wooden column; to the under surface of the bar are attached, at regular intervals, by a little wax or pomade, a number of balls or marbles; a lighted lamp is placed beneath one end of the bar, and as it conducts the heat, the wax melts, and the balls drop off in succession; thus showing that the conduction of heat by the metal is progressive, and not instantaneous.

If a copper bar of similar dimensions be experimented upon, the balls will drop off more rapidly, because copper is a better conductor of heat than iron; no two metals exactly agree in conducting power.

Let a cylindrical bar of iron, copper, or brass, twelve inches long and one inch diameter, highly polished, be enveloped tightly in half a sheet of thin writing-paper, and held as shown in fig. 28, so that the flame of a candle may touch the paper.

The paper will only blacken by the smoke, it

will not scorch in the least degree, because the heat, as it impinges upon the paper, is conducted away from it by the metal beneath, with such velocity as to be incapable of accumulating and burning the paper; but let a similar sized bar of wood be substituted for that of metal, and the paper will burn immediately, because the wood cannot conduct the heat from the point upon which it impinges.

Metals are the best conductors of heat, whilst wood, stone, and earths are the worst; a very striking instance of the bad conducting power of sand occurred at the siege of Gibraltar.

The red-hot balls used during the engagement were carried from the furnaces in which they had been heated, to the bastions upon layers of sand in wooden barrows, and this effectually prevented the heat from passing to the wood and setting it on fire.

The bad conducting power of sand may be illustrated by filling the palm of the hand with a heap of perfectly dry white sand, upon this a red-hot iron ball, the size of a small orange, may be placed, and borne for some time without inconvenience; the form of this remarkable experiment is shown in fig. 29.

The action of Fire and heat upon the three remaining Ancient Elements, Air, Earth, and Water, is productive of the most remarkable and important changes, which will demand particular attention; in this Chapter, the means of eliciting Fire, the nature of flame, and the conduction of heat, have been discussed, as introductory to other properties of this grand agent of the ancient and modern Chemist.

CHAPTER II.

AIR.

AN inquiry regarding the chemical nature of Air, will present information having intimate connexion with Fire, Earth, and Water.

The Ancient Element Air, is also called The Atmosphere, from the Greek ἀτμὸς, *vapour*, and σφαῖρα, *a sphere;* as it is a transparent, invisible medium, or ambient mantle, by which the Earth is enveloped, and accompanied during its axial and orbitual revolutions.

The direct altitude of the atmosphere from the surface of the Earth, has not been experimentally ascertained; it is conjectured to be fifty miles; and though this strikes the mind as a vast extent, it bears a very small proportion to the gigantic diameter of the Earth, which is eight thousand miles.

The atmosphere, therefore, is a mere film around the Earth; and for the sake of illustration, let an artificial globe, twenty inches diameter, represent the Earth; then a case, one-

tenth of an inch thick, enveloping it, would nearly denote the Atmosphere.

The total weight of the atmosphere has been ascertained, and it is expressed by the incomprehensibly enormous sum of five quatrillions, two hundred and eighty-seven trillions, three hundred and fifty billions of TONS; a weight nearly equal to that which a solid globe of lead would have, if sixty miles diameter.

The experimental evidence upon which this startling fact is established, will be partly described hereafter; suffice it now to state, that Air, though invisible, can be weighed and measured with almost the same facility as solids or liquids; so can all gases and vapours.

The only agents which elude the test of the balance, and all ordinary methods of measurement and confinement, are, Light, Heat, and Electricity; they are accordingly styled Imponderable Elements; but they exert more or less influence upon every kind of Ponderable matter.

Air is essential to the life of animals and vegetables, also to the existence of ordinary combustion; for deprived of air, no creature can breathe, no plant can grow, no fire can burn.

support flame, and this is at once evident by the highly inflammable Phosphorus ceasing to burn when it has abstracted the whole of the Oxygen, that is, about one-fifth of the original bulk of the air; or the fact of Nitrogen being a non-supporter of combustion, may be yet further proved by introducing the flame of a taper in the following manner:

The plate, with the bell-glass standing in it, must be lifted and quite immersed beneath the surface of water contained in a shallow tub or trough, and allowed to fall to the bottom, whilst the bell-glass is supported by the hand and shaken slightly to splash a little water into the floating saucer, and so cause it to sink.

This being done, the bell-glass must be sunk so that the level of the water within it coincides with that in the trough, the stopper may then be removed, and a lighted taper attached to the end of a wire plunged into the gas; the flame will be extinguished as perfectly as though it were dipped into the water.

Fig. 39 exhibits the requisite arrangement, and it is convenient to have a small wooden shelf fixed at one end of the trough, an inch and a half beneath the water, that the bell-glass,

and other glasses to be spoken of, may be occasionally supported upon it, to relieve the hands of the operator.

A small animal, or bird, put into Nitrogen would die instantly, but there is no occasion to mar the pure pleasures of Chemistry by such a wanton and cruel experiment, as the fact is established beyond a doubt, and it may be laid down as a general rule, that where a taper cannot burn, an animal cannot breathe.

The gaseous element thus destructive of life and flame is sometimes called Azote, from the Greek ἀ, not, and ζωή, life, but it is more commonly called Nitrogen, from νιτρον, nitre, and γενω, to generate, because under certain conditions it generates Nitre.

The word Gas is of German origin, implying spirit or essence, and it is generally borne by all aeriform matters which are unalterable by pressure or cold, such is Nitrogen, and as it cannot be analysed it must be regarded as one of the Elements of the Air. It presents the chemist with a perfect specimen of a non-supporter of combustion, and of an incombustible substance; for although there are many combustible elements and compounds, none of them

will burn in Nitrogen, nor will it burn under any circumstances.

A search after the principle or element of Air which does support combustion is rather difficult, because no agent has been discovered capable of taking away Nitrogen and leaving Oxygen; and therefore what Chemists call indirect action must be employed.

In the last experiment the Phosphorus took away Oxygen from the air to form the compound called Phosphoric Acid, and there are methods by which Oxygen may be taken in turn from this and exhibited in a pure state; but as these are rather too difficult and abstruse for mention here, other agents must be called into action, and even with them the operation will not be so directly evident as that of the Phosphorus leaving the Nitrogen, but the following experiment will serve as preparatory to the matter in question.

If a lump of bright lead be melted in a ladle on the fire, and kept in that state for some time, it tarnishes, and becomes encrusted with an earthy-looking powder; indeed the Alchemists thought that the metal was really transmuted into earth; but the theory of this change of

metallic lustre consists in the melted lead exerting affinity for the oxygen of the air, and slowly burning and producing a compound with the oxygen, called Oxide of lead, which is the powder alluded to above.

Many other metals thus tarnish or oxidize. Mercury does so in a most remarkable manner; its oxide is commonly known as Red Precipitate, in allusion to its colour, and its falling against the side of the vessel in which it is prepared.

This compound or Oxide of mercury is preferable to that of any other metal as a source of oxygen, for if it be made red-hot, the affinity between the mercury and the oxygen is overcome by the heat, or, in other words, the oxide is decomposed or analysed, and its elements may be obtained in their pure forms; the Mercury as a bright fluid metal, the Oxygen as a transparent invisible gas.

This curious and instructive experiment may be conducted by placing an ounce of oxide of mercury in the bulb of a two-ounce green glass retort, (the word retort is derived from the Latin *re*, back, and *torqueo*, to twist, because the neck of the vessel is bent nearly at a right angle,) the beak or end of which is then arranged so as

to dip [illegible] inches below the surface of the water contain[illegible] in the tub or trough, employed in a former experiment, whilst the bulb is supported on a metal ring, which slides along a metal rod, placed on a heavy foot, and called a retort-stand; the ring has a screw by which it may be adjusted at any height.

A small clea[illegible] [illegible]arcoal fire, contained in a chafing-dis[illegible] [illegible] furnace, is then to be placed beneath [illegible] of the retort, so as to heat it very gr[illegible]

The arrangemen[illegible] [illegible]wn in fig. 40, as well as a part to be n[illegible] [illegible]n the ensuing pages.

The heat of [illegible]oal fire immediately causes the escape o[illegible] [illegible]erous small bubbles from the beak of the retor[illegible], through the water, as in the experiment with the glass bulb and lamp, at page 60, and for the same reason; but these bubbles of air will cease in a few minutes.

As the retort becomes hotter, other bubbles will escape, at the same time that a grey film adheres to the arch or larger part of the neck of the retort, which was quite clean at the outset of the experiment.

These appearances announce the evolution

of Oxygen gas, which may be collected by taking a pint glass bottle having a wide mouth and ground stopper, applying a slight touch of pomade to the ground part, and then turning it round in the neck once or twice, so as to distribute the pomade between the ground surfaces, in order that there may be no difficulty in removing the stopper for the experiment to follow, and also to prevent the escape of the gas with which the bottle is to be filled.

The stopper may now be removed, and the bottle sunk in the trough, with its mouth upwards, so that the air may entirely escape and water take its place; this being done, the bottle must be turned mouth downwards and steadily lifted until exactly over the beak of the retort from whence the bubbles are issuing.

The bottle may be conveniently supported on the shelf of the trough, over a hole made in it an inch in diameter, beneath which hole the beak of the retort is placed; the bubbles will rise through the water in the bottle, whilst the water falls into that contained in the trough.

By this simple arrangement, the Chemist collects the greater number of gases with which he is acquainted; and whilst the operation is

inserted; it must then be inverted, and its neck plunged beneath the water in the trough; the stopper is to be withdrawn whilst in this position, and the bottle, still full of water, carefully moved upon the shelf.

The plate containing the bell glass of nitrogen must be removed into the trough, and both plate and saucer sunk, as directed at page 64; and then, by sliding the mouth of the bottle rather more that half way off the shelf, the mouth of the bell glass is to be brought close against it, and slightly inclined as shown in fig. 45.

Allow Nitrogen from the bell-glass to bubble through the water, as in the experiment with the air of the wine-glass at page 56, which is done by depressing the top of the bell-glass with one hand, whilst the other holds the bottle; the nitrogen will rise into it; allow it to do so until four parts of the bottle are filled, then slide it quite on the shelf; let the bell-glass be raised upright, but still with its mouth under water; and whilst in this position the plate can be again placed beneath it, and both lifted from the trough, provided there remain any nitrogen worth saving; if not, the bell-glass may be un-

toppered, and lifted out, without any such precaution.

The operation now described is one of the many methods by which gases may be transferred from one vessel to another.

The remaining division of the marked bottle has now to be filled with Oxygen from one of the stoppered bottles; and this can be done, by plunging the neck of the bottle of oxygen beneath the surface of the water in the trough; then withdrawing the stopper, then sliding the mouth of the marked bottle from the shelf, and bringing that of the other into the same position as last described for the bell-glass, when oxygen will bubble up, and fill the marked space. The stopper of the marked bottle must now be inserted under water, and then it can be lifted from the trough, and placed in its usual position upon the table.

If a portion of oxygen remain in the other bottle, it may be preserved by stoppering under water.

The operation is more easily performed than described; and a very little practice beforehand in transferring air from one bottle or jar to another will ensure success.

The marked bottle contains a Mixture of Nitrogen and Oxygen, in nearly the same proportions by measure as they exist in Air, namely, Four parts of the former, and One part of the latter; its power of supporting combustion may be examined; and having lighted a small wax taper attached to the end of a wire, the stopper can be removed, and the taper introduced; its flame will be neither extinguished nor increased, but it will burn with precisely the same quiet brilliancy as in the surrounding Air.

Having thus examined the essential chemical Elements of Air, some interesting phenomena dependent upon the combined effects of its expansion by heat, and change by actual flame may be next introduced for consideration.

Air, Gases, and Vapours, when heated, expand in bulk, and diminish in weight; therefore, if unconfined, they have a tendency to ascend through the colder and heavier surrounding atmosphere; no better illustration of this fact can be presented than the Fire-balloon, its ascent depending upon the levity of heated air, and the products of the combustion by which it is heated and partially decomposed.

The Fire balloon is a large globe of thin

r, having an aperture through which it may
flated; in fig. 46 the balloon is shown in a
id state, its aperture is to be held over a
himney, four inches diameter, two feet high,
eeding from a low funnel one foot diameter,
orted on a tripod two inches high, and
ring a tin plate, holding a flame burning
a sponge soaked in spirits of wine, fig. 46 *a*.
The products of the combustion of spirits of
, namely, carbonic acid and watery vapour,
heated, together with a quantity of air
ed and partially decomposed by rushing
ath the funnel to the flame, ascend into the
oon, which gradually distends until quite
as shown in fig. 47; and then, if loosed from
hand, it mounts rapidly to a considerable
ht in the surrounding atmosphere; but as
contents cool, the balloon loses its ascen-
al force, and falls slowly towards the
nd.

The first ascent of an experimenter into the
osphere, was by means of an enormous Fire-
oon; and in order that it might continue
yant, a grate was suspended in the centre of
aperture, filled with burning straw; this the
enturer replenished, or allowed to decay,

from time to time, according as he desired to ascend or descend; several fatal accidents subsequently happened in consequence of the fire communicating with the paper of the balloon; this dangerous invention is superseded by the Gas-balloon, which will be described hereafter.

Smoke from a chimney ascends into the air, for the very same reason as the Fire-balloon; and as all the comforts of an English fire-side depend upon the free and perfect egress of smoke from the burning fuel, a few observations concerning the matter may be here introduced.

When fuel is kindled in a common grate, it requires a plentiful supply of air, in order that it may burn freely; therefore, bars are placed below, as well as in front of the fire-grate, that air may have access to all parts of the fuel; and if the smoke and vapour resulting from the combustion ascend quickly into the chimney, and from thence into the open air, it is commonly said to draw well.

Most persons attribute to the chimney some inherent or specific action, by which it draws smoke and vapour from the fire; but this is not the case, it being merely a pipe or outlet for the products of combustion; and these being heated,

ıd lighter than air, ascend through it as the adiest means of escape into the external mosphere.

The following is the whole theory of the atter; the fuel is kindled, or, in other words, pid chemical affinity is induced between its flammable elements and the oxygen of the air the apartment.

The products of the combustion are nearly nilar to those of the candle-flame, formerly entioned; therefore a portion of air is deprived oxygen, the nitrogen heated, as well as the rrounding air; both are thus rendered lighter an the great bulk of colder air of the apart-ent, and therefore ascend the chimney; air from e apartment rushes forward to supply the fuel, that the flame of the fire is constantly draw-g upon the air of the apartment for support, d as in the case of the candle flame at page 24, e air which has thus yielded oxygen, and come heated, and formed new heated products, ıst have free escape, for if it be retarded as in dly-constructed chimneys, then it rolls back th the smoke in sooty volumes and fills the artment.

Suppose the chimney to be perfectly con-

structed, it is absolutely essential that as much air should in some way enter the apartment, as the fuel consumes or causes to ascend in a heated state, and the endeavour of the air in the external hall or passage to gain entrance and rush towards the fire, is announced by a whistling sound through the keyholes and crevices of the doors and windows; the chief entrance of the air to the apartment is through the space between the door and the carpet; this causes what is commonly called a draught, the danger of which is proverbial; it is a current of air which rapidly deprives the animal frame of heat, and produces the disagreeable and often fatal effect popularly called a cold.

If all crevices be stopped so as to prevent a draught, then the chimney refuses its office, the smoke descends into the apartment, and in many houses a window or door must be kept partly or even quite open, to admit the required supply of air, or otherwise the inmates of the apartment could not endure to sit there for the smoke; but this is only remedying one evil by the introduction of another, for it is by no means agreeable to remain in such a thorough draught.

It is extremely difficult to admit a proper

pply of air to the fire without causing incon-
nience to the inmates of the apartment; some
dmirable contrivances have been successfully
dopted, but they are too complicated for de-
cription in this general inquiry.

To warm an apartment comfortably by a
common fire, the grate should be placed as near
the hearth as possible; it should be wide and
shallow, so that the heat may be thrown directly
upon the floor; this imparts warmth to the air
which sweeps over its surface; this warmed air
ascends, colder air descends, in its turn becomes
warmed, and thus currents are established which
soon bring the temperature of the apartment to
a proper degree.

In the ordinary method of warming apart-
ments by open fires, even when the fire-places
are more judiciously constructed, much heated
air is lost by passing up the chimney; therefore
to economize fuel, more particularly when very
large apartments are to be warmed, the coal is
burned in close stoves; the well-known German
stove is an instance.

The advantages of this invention consist in
the very small quantity of fuel which will main-
tain a very strong fire; the whole mass of the

iron stove becomes heated to a considerable degree, and as it is usually placed in the middle of the apartment, with its iron chimney or flue partly perpendicular and partly horizontal, the whole surface throws off heat very powerfully, and the air rushing forward to support the fire, impinging upon the heated surface becomes warmed instantly; it ascends, cold air descends, becomes warmed and ascends; and thus currents are more rapidly established, and the apartment more effectually warmed than by the combustion of the same weight of fuel in the ordinary fire-grate.

Very little heat is lost if the flue be tolerably long, and very little smoke passes out at its extremity, because the draught of air through the door of the stove is rapid and powerful, so that all the inflammable matter of the coal is consumed, (like that of the oil in the Argand lamp at page 32,) which is never the case in a common grate, and hence formerly the necessity of employing a wretched climbing-boy to cleanse away the unburnt carbon or soot from the interior of a chimney; this is now effected by simple machinery.

It should be remembered that the German

stove requires a supply of fresh air, as imperatively as an open fire-place, so that a draught is the inevitable consequence of its employment, unless it be supplied with air from a tube entering its lower door and opening into the external air; and if this be done, then there is very little chance of the air in the apartment being renewed; and unless the door of the apartment be opened frequently to admit fresh air, the whole atmosphere will become insufferably heated and unpleasant.

Care should always be taken that the iron-work of a stove never becomes red-hot, or it will gain the power of vitiating the air by combining with the oxygen, as the melted lead was stated to do at page 67; and though the apartment will be more powerfully heated by the red-hot iron, the air will be rendered unfit for the support of life.

In London, the air generally contains minute dust diffused throughout its volume, and this dust coming into contact with the red-hot iron of a stove, is burned, and produces a very oppressive odour.

The abstraction of oxygen from air, and the combustion of dust, by the action of the red-hot

iron, are the principal causes by which apartments warmed by overheated stoves are rendered so proverbially unwholesome.

It is a very excellent plan to place a vessel of water on the top of the stove, that the water may evaporate and supply the air with moisture, and thus correct its oppressive dryness in some degree.

Water is always naturally present in the atmosphere in the state of vapour, and is indispensable for the support of life, as will be more particularly shown hereafter.

A very ingenious self-acting apparatus for opening or closing the window of an apartment, in proportion as the air becomes hot or cold, may be understood from an examination of fig. 48.

This represents the wall of an apartment having an opening near the ceiling, provided with a sliding window-sash, glazed in the ordinary manner; the upper part of this is attached to a rope, which passes over a pulley above the top of the opening, and then over another pulley at the same level, though supported at the end of a bracket, projecting one foot from the wall.

The end of the rope proceeds downwards,

is attached to a ring on the upper part of a n iron bulb, twelve inches diameter, having iron tube, one inch and a half diameter and ree feet long, connected with it by close sol- ering, and open at the lower end, which dips nto mercury, contained in a cylindrical iron essel, rather larger than the tube, but of the ame length.

A portion of mercury is also contained in the tube attached to the bulb, just sufficient to render its weight equal to that of the window-sash, so that it may close the opening at the outset of the adjustment. The apparatus being thus arranged, if the air of the apartment become very hot, the air in the bulb will expand and force out a portion of mercury from its tube; thus rendered lighter, the bulb will ascend, in so doing, the window-sash will descend, and allow the heated air of the apartment to escape through the opening; on the other hand, if the air of the apartment become cold, that in the bulb will likewise, and will contract, so that a portion of mercury will enter the tube; thus rendered heavier, the bulb will descend, and the window-sash ascend to close the opening.

The ventilation of apartments and buildings

depends upon the escape of the air, which is heated and vitiated by respiration and combustion, and the entrance of fresh air to supply its place.

As heated air always ascends, it is the common practice to make an opening in, or near the ceiling for its escape, but a descending current of cold air is very likely to enter the apartment through the opening at the same time, unless the tube or flue connected with the opening be heated; this is effected in theatres by suspending the gas chandelier beneath a large metallic funnel, the tube of which passes into the open air.

When the gas is kindled, the funnel and tube become extremely hot, the vitiated air rises rapidly towards it and escapes, whilst cold air from without cannot enter, because the moment that it comes into contact with the heated tube it expands, becomes lighter, and ascends in company with that which is rushing from the body of the house.

Fresh air is allowed to enter through proper openings, situated near the floor of the house, and thus a large current sweeps through and proceeds upwards with the products of respiration and combustion into the external air.

From the preceding statement it must be evident that the Air, or Atmosphere, is a boundless source of useful and interesting information, and did the limits of this general inquiry admit, much more might be said regarding the Mechanical and Chemical properties of this wonderful medium.

Sufficient has been said to prove that the Ancient Element Air, is a Mixture of the two Modern Elements, called Nitrogen and Oxygen. The latter will again claim attention as an Element of Earth, and Water.

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AMORC, the International Rosicrucian Order, [illegible] of men and women interested in questi[illegible] of life nature, in self-evolution, and in securing [illegible] logical answers to these questions. Therefore, th[illegible] can show you how, to your satisfaction, you may secu[illegible] the knowledge that lies behind the veil. They pra[illegible] moral alchemy, mental alchemy, and transmuted e[illegible] mastery principles into golden manifestations; th[illegible] found the key to life and death, health and diseas[illegible] failure and success, power and mastery.

HELP US SPREAD THE GREAT LIGHT

Rosicrucians are pledged to spread the Great Lig[illegible] in every possible way. It is truly a joy to help brin[illegible] happiness, health, and prosperity into the lives [illegible] others. You may not know just how the Rosicrucia[illegible] can aid you in your daily problems, but the way w[illegible] be pointed out to you, and you will become one [illegible] the numerous thousands in the world who share [illegible] knowledge of this very old and honored fraternity.

And now a new book—not for sale—but LOA[illegible] to sincere students who seek self-evolution, has [illegible] written by Sri Ramatherio, Scribe. It is called [illegible] Light of Egypt." It contains the strange story [illegible] Rosicrucians and their secret doctrines and shows [illegible] the absolutely sincere and worthy seeker of today [illegible] BECOME a crude scientist and adept of the kno[illegible] and attain such mastership as constitutes Rosi[illegible] Power. Only those sincerely, however, promising [illegible] the same consideration, thought and due consid[illegible] book. Send a letter stat[illegible] should apply these efforts, will be sent, postpaid. Ad[illegible] date, and the [illegible]

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amined with a magnifier, they will be found to resemble it, and they are commonly grouped together as shown in fig. 69.

The origin of the term Crystal has been explained at page 96; but here it may be stated, that the term Salt, is not confined to the common salt which is known in domestic use, for it is generally applied to a variety of compounds very different, and having no saline taste; thus, chemically speaking, Marble, is a salt of lime, and Pearlash, a salt of potassa, the term being used for mere convenience; some salts are insoluble in water, others soluble; some are transparent and colourless, others opaque and coloured; some are poisonous, others are harmless.

Sulphate of magnesia is very soluble in water, but insoluble in spirits of wine; it is well known that spirits of wine will mix readily with water; and these two facts may be taken advantage of for the performance of the following striking and instructive experiment.

Let an ounce by measure of the solution of sulphate of magnesia, drained from the crystals already mentioned, and which is saturated with the compound, be poured into a large wine-glass,

which is to be filled with strong spirits of wine; then stir the two liquids together with a small rough stick, and in a few seconds a white mass appears, which sets or concretes so hard and solid to the glass and the stick, that the former may be lifted from the table by the latter.

The theory of the experiment is obvious; the spirits of wine exerts chemical affinity for the water in which the sulphate of magnesia is dissolved, and therefore combines with it; whilst the salt thus suddenly deprived of water, is liberated or precipitated in a solid form, and not regularly crystalline, for a reason which will be stated in the ensuing chapter.

Crystallized sulphate of magnesia consists of

	Parts.
Sulphuric acid . .	32·52
Magnesia	16·26
Water	51·22
	100·00

The substance called Talc, is a magnesian mineral; it is found in large blocks, which may be easily cleaved into thin leaves, so beautifully transparent, as to admit of being used as a substitute for glass in window frames; and in this

application talc possesses an advantage over glass, inasmuch as it will not shatter by a blow.

Asbestos, so called from the Greek, ἀ, not, and σβερος, to extinguish, is another magnesian mineral, and from the circumstance of being found in long soft flexible fibres, is popularly called mountain flax: these fibres admit of being spun into threads, which may be woven into a textile fabric by the loom; the ancients were well acquainted with this property of the mineral, and its indestructibility by fire, and therefore employed the lapideous fabric as an envelope for bodies which were consumed on the funereal pyre, so that its incombustible nature might prevent human ashes from contamination with those of the fuel.

Asbestos was likewise employed by the ancients for making the wicks of their everlasting lamps; the moderns occasionally use it for a similar purpose, where a flame is required to continue burning for many days, without the wick requiring attention.

Another magnesian mineral, greenish, soft, and unctuous to the touch, is popularly called Soap-stone; the natives of China and Japan carve it into very grotesque figures and groups.

French chalk is a variety of soap-stone; its use for absorbing stains of grease is well known.

These are all the experiments that can be here adduced concerning Magnesia and its compounds; it now remains to say a few words regarding Baryta and Strontian, which are two curious substances, well known to Chemists, though by no means so plentiful as Lime and Magnesia.

In several counties of England, a heavy mineral is found, which contains a peculiar substance, called Baryta, from the Greek βαρος, *heavy;* it was formerly regarded as an Earth, but now as an Oxide of an inflammable metal, called Barium, which is very difficult to obtain.

Baryta consists of

	Parts.
Oxygen	10·4
Barium	89·6
	100·0

It is more alkaline, caustic, and poisonous than lime, and forms many natural and artificial compounds; it combines with a powerful acid, called Nitric acid, producing a crystalline salt, called Nitrate of Baryta, which consists of

	Parts.
Nitric acid	[illegible]
Baryta	[illegible]
	100.

This salt can be procured at a very cheap rate, being largely consumed in the art of Pyrotechny for producing an emerald-green flame; the other materials to be mentioned can also be obtained without difficulty; they are Sulphur, Chlorate of Potassa, and Sulphuret of Antimony; these must be separately weighed out in the following proportions for the Green fire composition:

	Parts.
Nitrate of Bartya . .	77
Sulphur	14
Chlorate of Potassa . .	5
Sulphuret of Antimony	4
	100

The scale pan must be carefully cleansed after the removal of each substance; they are then to be separately reduced to fine powder in a mortar, taking care to wash and dry it and the pestle between each operation; for if these cau-

dissipated, whilst pure water trickles from i
and is received in a clean bucket or other sui
able vessel; the earthy and saline matters remai
in the boiler of the still, and by constructin
the apparatus of sufficient magnitude, hundred
of gallons of distilled water may be obtained.

Distilled water, or pure water, which durin
the remainder of this chapter will be simpl
called Water, is a liquid perfectly colourles
transparent, inodorous, tasteless, and unchange
able, if kept in vessels upon which it can exe
no chemical action, as in bottles of gold, silve
or platinum; in the heat of summer it is alwa
liquid, but in the cold of winter changes into a soli
called ice, and there is an immutable degree,
temperature at which this remarkable transitio
ensues, which can be proved by the Mercuri
Thermometer: this is a very simple yet beaut
ful contrivance for denoting changes of natur
and artificial temperature, by the expansion an
contraction of fluid mercury; its most usef
Chemical form may be understood from an i
spection of fig. 74.

The Thermometer is constructed of a fir
glass tube, having a small bulb blown on or
extremity, which contains mercury, as likewis

does a certain portion of the tube or stem; this is attached by two metal loops to a strip of box-wood or ivory, called a scale, in consequence of being marked or graduated into many divisions or degrees, two of which, namely 32° and 212°, being distinguished by the words Freezing, and Boiling.

Let the bulb of the Thermometer be placed in a small cup full of water, which is afterwards introduced into a jar containing a mixture of equal parts of finely-powdered ice and common salt; this forms what is popularly called a Freezing mixture, on account of its common employment by the confectioner for producing cream and water ices; it is also used by the Chemist for obtaining artificial cold, when necessary for experimental investigations.

The theory of the action of the ice and salt, is too abstruse for this discussion, therefore content with having a source of cold at command, let its action with the water be proceeded with.

On the immersion of the thermometer into the water, the mercury in its stem may be at, or near 60 degrees, but as the water cools by the frigorific action of the surrounding mixture, the mercury gradually falls, until it becomes sta-

observed to fall for the space of two or three inches, so as to leave the upper end of the tube empty.

The mercury falls, because the surrounding atmosphere is unable to balance a greater height or column of the heavy metal; and if the mercury remaining in the tube could be removed, and accurately weighed, the result would present the weight of a column of the atmosphere, of equal diameter with that of the bore of the tube.

The mercurial column and the aërial column mutually balance each other; if the latter fluctuate in weight, the former will in height, because there is no air in the tube above the mercury; it is void of air, or a vacuum; and if the instrument be slowly inclined into a horizontal position, the mercury will be found to fill it, which it could not do if air were present, any more than the water could enter the wine-glass at page 54, whilst full of air.

The tube of the Barometer is made thirty-two inches long, that there may be space for the ascent of the mercury, when urged upward by the external pressure of the air upon that in the cistern; if it were only thirty inches long, there would be no empty space in many states of the

atmosphere, because it would be enabled to balance a column of mercury of that height; and the tube would remain full, until the weight of the atmosphere diminished, and then the mercury would fall, to a certain extent.

The enormous weight of the Atmosphere already mentioned, was detected by the Barometer; and the following account may explain the principles of the operation:

If a tube, exactly thirty inches long, and one inch square, closed at one end, be filled with mercury, the metal will weigh fifteen pounds; if the open end of the tube be inverted into a cistern of mercury, in certain states of the atmosphere, the tube will remain full: from this it is concluded, if a ponderous column of mercury can be thus supported by the atmosphere, that it must be pressing with a weight equal to Fifteen pounds upon every square inch of surface.

15
POUNDS.

By calculating the number of square inches upon the surface of the entire globe, the total weight of the atmosphere is discovered to be represented by the enormous sum alluded to above.

This weight of air, though constant upon the whole, is liable to local variations, and these materially affect the boiling of water; and though it is true that on the scale of the thermometer 212 degrees announces the Boiling Point; yet, unlike that of 32 degrees, or the Freezing Point, it has reference to some Fixed or Standard weight of air; or, in other words, 212 degrees of the Thermometer is the point at which water boils, if the mercury in the Barometer stand at the 30 inches marked upon its scale, at the level of the sea; then the Air is said to be at its mean or standard weight or pressure.

On a day when the mercury in the Barometer stands at, or near 30 inches, if a tin cupful of water be set over the flame of a lamp, it will soon boil briskly; that is to say, the heat overcomes the pressure of the air which tends to preserve the water in a liquid state, and converts it, in defiance of this pressure, into vapour

or steam, in which the bulb of the Thermometer may be held for a few seconds to warm, and then plunged into the boiling water; the mercury will rise rapidly in the stem, and at length become stationary very near 212 degrees, or the Boiling Point; and there it will remain, however furiously the water may boil.

If the experiment be repeated on a day when the mercury in the Barometer stands at 28 inches, the Thermometer will not indicate 212, though the water apparently boils the same as before; but the mercury in the Thermometer stops at 210 degrees, or thereabout, because there is not so great a pressure of air upon the water as before, and the heat can more easily raise the water into steam; in fact, the boiling water is about two degrees colder than in the former experiment.

The mercury in the Barometer is sometimes considerably higher than 30 inches; and then, if the boiling of water be tried, the mercury in the Thermometer will pass beyond 212, because there is a greater pressure of air upon the surface of the water; and the heat having this pressure to contend against, renders the water hotter before it can rise into steam.

mixture, it will not freeze until the mercury in the Thermometer sinks many degrees below 32, namely, to 0°, or zero of the scale.

From the foregoing experiments and observations, it becomes apparent that 212 is called the Boiling Point of water when perfectly pure, and heated in an open vessel, the air being at the standard pressure of 30 inches; the Freezing Point, or 32 degrees, is immutable under every change of pressure, and can only be affected by substances largely dissolved in water; hence it is that the salt water of the ocean remains current, whilst the fresh water of the river is locked in ice.

The manner in which water becomes heated to its boiling point yet remains for explanation; this may appear a very simple matter of inquiry, but it will be found to involve several curious facts of Chemical philosophy. The facility with which water boils would naturally lead to the conclusion of its being a good conductor of heat; but the following experiments will prove the contrary:

Nearly fill a tall ale or champagne-glass with water; upon its surface pour a tea-spoonful of ether, which, being a very light fluid, will float,

	Parts by Weight.
Nitrogen	75·55
Oxygen	23·32
Carbonic acid	0·10
Watery vapour	1·03
	100·00

	Parts by Measure.
Nitrogen	77·50
Oxygen	21·00
Carbonic acid	0·08
Watery vapour	1·42
	100·00

Water enters into chemical combination
many substances, and is often retained by t
with very powerful affinity, so that ordinary
ing will not expel it; several of those beau
natural and artificial productions called cry
owe their form, texture, and brilliancy t
presence; this is the case with crystal
sulphate of lime, which are frequently of
size and transparency as to be used as a su
tute for glass, but the transparency depends
chemically combined water, though the
stance does not feel damp to the touch, and

crystal be heated in the flame of a lamp, it crumbles into an opaque white powder, as the water evaporates.

Crystallized sulphate of magnesia contains more than half its weight of water, which may be expelled by heating it in a small ladle or crucible, leaving a dry, white, shapeless, or amorphous mass; and in the experiment at page 132, with a strong solution of sulphate of magnesia and spirit of wine, the salt was precipitated white, opaque, hard, and amorphous, because the spirit combined with, and removed, the water essential to the production of crystalline form; this is technically called Water of crystallization.

The crystals of alum, at page 102, likewise owe their beauty to the presence of water, and if it be expelled by heat as above, a white crumbling mass remains, which is popularly called Burnt Alum.

Substances containing combined water, as the foregoing natural and artificial crystals, are called Hydrous, and when deprived of it, Anhydrous; both terms are derived from the Greek, the one indicating the presence, and the other the absence of water.

In the Introductory Chapter, Water is stated

and the tube placed in the water of the trough as there directed.

Hydrogen will be evolved, and may be collected in bottles filled with water in the trough, as at page 69, taking care that the gas, which is first obtained in a pint bottle, be suffered to escape by lifting it from the trough, because it is not pure, but mixed with the common air, driven from the bottle containing the zinc and acid.

The inflammability of Hydrogen has been adverted to at page 36, but here it may be remarked that the gas will not support combustion; let a bottle full be held with the stopper downwards, and the stopper taken out in such position, then thrust a lighted taper into the gas, it will instantly burn with flame, but the flame of the taper will cease.

The bottle must be held in an inverted position when the stopper is withdrawn, as shown in fig. 86, or otherwise the Hydrogen would escape, it being permanently lighter than air, as may be proved by opening a bottle full of the gas, as it stands upon the table; leaving it a minute, and then introducing a lighted taper, it will burn quietly in the Air, which has descended into the bottle and expelled the Hydrogen.

On the other hand, if a bottle full of Hydrogen be opened in the inverted position, and so held for a few minutes, the gas will not escape, because, being much lighter than air, it cannot fall through air, but will kindle at the flame of a taper.

A very beautiful experiment, in illustration of the levity of the inflammable gaseous element now under examination, may be performed by following the next instructions.

Let two similar-sized wide-mouthed bottles, one containing Air, the other Hydrogen, be held in an inverted position, with the stopper of each removed; then, by inclining the bottle containing Hydrogen, let its mouth be placed directly under that of the other, as shown in fig. 87.

The position is exactly the reverse of that used for ordinary pouring; the Hydrogen will ascend and take the place of the Air in the bottle above, whilst it descends and takes that of the hydrogen, as the application of a lighted taper to the mouth of each bottle will prove.

Another experiment yet more remarkable is the following; let a quart bell-glass be filled with hydrogen in the trough, and then gently lifted from the surface of the water, with its

mouth downwards, so as to admit of the introduction of a small tumbler, fastened to the end of a stout wire, with its mouth also downwards, as represented in fig. 88.

Let the tumbler be passed upwards, until it touches the interior of the dome of the bell-glass, then steadily drawn out, and moved at some distance from the bell-glass, to the flame of a taper; the contents will kindle, and prove that Hydrogen has been drawn down, and out of the bell-glass; these last experiments with Hydrogen are directly opposed to those with Carbonic acid at page 109.

In consequence of its inherent and permanent levity, Hydrogen was formerly employed for inflating balloons, but is now superseded by the gas obtained from coal, which is found sufficiently buoyant for the purpose, and can be obtained with more facility at a cheaper rate; yet the inflation of a small balloon by hydrogen is a pleasing experiment, and may be very easily performed.

Let a small balloon, about six inches diameter, be compressed gently between the hands, so as to expel the common air, and then tied with its neck over one end of a straight metal pipe,

six inches long and one quarter of an inch diameter, the other end being thrust through a cork placed in the mouth of a pint bottle, containing zinc and diluted acid, as at page 35: as hydrogen evolves it will be received in the balloon, and when fully inflated, upon removal from the pipe, the balloon will ascend with great swiftness.

It frequently happens that the heat of the action between the materials in the bottle causes steam to rise with the hydrogen, and such steam condensing in the balloon, renders it too heavy for the expected ascent; therefore, instead of employing a simple pipe, as just directed, it is advisable to use a glass tube about one foot long, three quarters of an inch diameter, tapered to pass through a hole in the cork that fits the mouth of the bottle; and to fill the tube with fragments of quick-lime, then to its upper part adapt a cork and smaller tube to fit the neck of the balloon, as shown in fig. 89.

In such arrangement the lime will absorb and arrest the steam or vapour of water if it rise, and the hydrogen thus dried will enter the balloon, inflate it, and the ascent will ensue with certainty.

Hydrogen, when pure, burns quietly, but when mixed with Air or Oxygen, it burns with a violent explosion, therefore the greatest care must be taken in all experiments, that neither air nor oxygen becomes mingled with it; whenever it burns, the product of its combustion is water, as mentioned at page 36.

Knowledge of the composition of Water is a most important fact in Chemistry; it consists of

	Parts by Weight.
Oxygen	88·9
Hydrogen	11·1
	100·0

This fact enables philosophers to explain many phenomena, which were once mysterious, and it also proves how wonderful must be the power of attraction, called Affinity, in disposing two Gases to combine and produce a Liquid; for no reasoning would ever lead to the conclusion that Water, the Ancient Element, so opposed to Fire, consisted of a Combustible, and a Supporter of combustion; or, in other words, of one of the elements of all ordinary Fire, and another of the surrounding Air, namely, Hydrogen and Oxygen; and perhaps the time is not

far distant when Water will be employed as the most fertile source of Fire.

The inquiry concerning The Chemistry of The Four Ancient Elements here terminates: its object has been to excite feelings of interest regarding the enchanting Science of Chemistry, rather than to give minute information; and if the few treasures which have been displayed from this vast mine of Natural Knowledge induce those who are unacquainted with its resources, to enter upon the pursuit of more, they will find it rich and inexhaustible.

They will find that, unlike its parent Art of Alchemy, Chemistry is a Science having no narrow range nor selfish aim, but an intimate connexion with the best and highest interests of man, teaching him the just and proper value of the productions of the beautiful globe upon which he dwells, and their practical applications to his wants, his comforts, or his luxuries; and, above all, leading him to acknowledge, with reverence and gratitude, the Wisdom, Power, and Goodness of The Great God, by Whom all things were Created.

APPENDIX.

AS several of the agents which are required for performing experiments in illustration of the Chemistry of The Four Ancient Elements, demand considerable caution to be exercised in their management, a few details concerning the matter will form a useful Appendix to the Essay.

LIME WATER.—*Page* 22.

This valuable test for detecting Carbonic acid may be prepared as follows;

Take two ounces of clean chalk, (carbonate of lime,) broken into pieces about the size of hazel nuts, put them into an iron ladle, which is then to be set in a bright glowing fire, and allowed to continue red-hot for an hour, at the expiration of which nearly the whole of the carbonic acid will have escaped. Remove the ladle, allow it to cool, then shake out the substance it

contains upon an earthenware plate, it is Quick-lime; gently pour water upon it, and the lumps will soon crumble away with a crackling noise, and the evolution of much heat and steam. Thus the lime is slaked, and Hydrate of Lime obtained; this must be placed in a quart glass bottle filled with water; the cork or stopper being then inserted, the bottle must be shaken two or three times, and afterwards allowed to rest; the greater portion of the lime will subside, whilst the clear liquid above is Lime-water; it must be carefully poured off into another bottle, and preserved from the air by a well-ground stopper, for use. Fresh water may be added to the sediment in the quart bottle every time that clear lime-water is decanted, and thus a stock may be kept without difficulty; in the course of time, the lime will be exhausted, and this is detected by the clear water ceasing to restore the blue colour to litmus-paper which has been reddened by an acid.

Fresh lime must then be prepared, &c.

SPIRITS OF WINE.—*Page* 23.

Chemists generally call this liquid Alcohol, a term derived from the Arabic, implying *sub-*

tlety; it must be kept in a strong glass bottle with an accurately-ground stopper.

Spirits of wine, or Alcohol, is highly inflammable, and should never be poured from the bottle to any vessel near or level with the flame of a lamp or candle. The vessel into which the alcohol is to be poured must invariably be set upon the table, because the volatile vapour of alcohol is heavier than air, and will not rise high enough to encounter the flame of a candle or lamp, set in a candlestick, or on a pillar of the usual height. If the bottle of alcohol and the glass or other vessel into which it is to be poured are held level with or over the flame, whilst in the act of pouring, the heavy vapour descending may kindle, and envelope the hands in flame they are certain to drop the bottle and glass, the contents of both will float over the table, or the cloths of the operator, as liquid flame; great danger is thus incurred, because flame always ascends, and the face may be dreadfully burned

Should an accident happen with Alcohol, its flame on the table may be extinguished by throwing over it a thick wet woollen cloth, and that on the person of the operator by a similar cloth quickly thrown over the part which is suf

fering; for, be it remembered, that the flame cannot burn without air, and the wet cloth prevents its access. In a case of great danger, it is advisable to lie upon the floor, and cover the whole person with the hearth-rug, which will extinguish the flame effectually.

Spirits of wine or Alcohol is a very excellent fuel for lamps which are required for heating glasses, &c., as at page 60, because it deposits no soot, the products of its combustion being only carbonic acid and water. A spirit-lamp should have a cap or cover to put over the wick to prevent the Alcohol from evaporating when the flame is extinguished.

ETHER.—*Page* 29.

This liquid must be kept in a strong glass bottle, with an accurately-ground stopper, tied over with glove-leather, because it is more volatile than Alcohol, and the expansion of its vapour in a warm room frequently forces out the stopper, if not thus secured.

Ether is highly inflammable, and the same precautions as those given regarding alcohol must be observed in pouring it from the bottle

to another vessel; its vapour is heavier than that of Alcohol, and its flame far more difficult of extinction by the means described, but none other can be employed.

To avoid the chance of an accident, it is best to decline making experiments with Ether by candlelight; but even in daylight the flame of the paper employed to kindle the Ether, as at pages 29 and 30, should be carefully held above and away from the tin cup into which the ether is poured, until the moment that it is required to be inflamed. Strict care must always be taken to insert the stopper of the bottle of Ether, to tie it over with the leather, and then remove the bottle away from the table upon which the tin cup or other vessel stands containing the requisite portion of ether to be kindled.

PHOSPHORUS.—*Page* 29.

This element is usually sold in small rods, about the size and length of cedar drawing-pencils; it is soft like wax, very inflammable, and must be kept in a vial full of water. Phosphorus, when required for an experiment, must be shaken from the vial into a basin of water;

then removed by means of a pair of scissors, or pliers, and placed upon a flat board; the proper portion of phosphorus can then be cut off with a pen-knife, and the remainder replaced in the vial, filled with water as before. The small portion of phosphorus, recently cut off, must be removed on the point of a knife to a few folds of white blotting paper, and gently pressed between the folds to absorb the adhering water. This being done, remove the phosphorus by means of the knife, and place it in the small ladle.

Dry phosphorus must neither be held between the fingers nor strongly rubbed, because it will inflame by warmth or friction, and produce most painful burns, which are extremely difficult to heal.

By following these directions, Phosphorus may be safely experimented upon; but should it accidentally take fire and burn the hands, let them be plunged instantly under water, which will extinguish the flame, and whilst there the phosphorus must be perfectly removed from the injured part, which afterwards will require the same treatment as an ordinary burn.

SULPHURIC ACID.—*Page* 35.

This powerful acid is a transparent, colourless, heavy liquid, and though not volatile at common temperatures, it must be kept in a strong glass bottle, having an accurately-ground stopper, for it attracts water from the air, and becomes weakened.

Sulphuric acid is dangerously corrosive, producing most painful and troublesome wounds if it fall upon the person; it must be poured with the greatest caution from the bottle into other vessels, without gurgling, and during the operation it must not be held level with the face, lest it accidentally splash, and do injury: it is not inflammable. If injury be received from sulphuric acid, water must be plentifully applied with a large towel to the part, to wash away the acid; a little water will only increase the burning sensation. If the acid be spilled upon the table, a thick flannel, well soaked in water, will remove the greater part, but some will remain, and its effect may be neutralized by washing the table over with whiting and water, or carbonate of soda and water, until effervescence ceases.

The towel and funnel must be soaked in water containing carbonate of soda to neutralize the acid which they have absorbed, for if suffered to remain it would corrode and destroy them.

If sulphuric acid fall upon the clothes, water must be applied, and then carbonate of soda, smelling salt, harts-horn, or ammonia to neutralize its effects.

When experimenting with sulphuric acid, the bottle containing it must always be set in an earthenware plate, so that any drops adhering to the lip of the bottle may trickle down into the plate, and do no injury to the table.

Sulphuric acid must never be added suddenly to water, for intense heat will be evolved, which will break glass vessels, and then much damage will ensue.

HYDROGEN.—*Page* 36.

In evolving Hydrogen by the action of diluted sulphuric acid upon Zinc, the effervescence must be allowed to continue for several minutes before the application of flame to the end of the brass pipe; the object of this delay is to ensure the expulsion of common air from the bottle; if this precaution be neglected, and the flame be applied

immediately after the insertion of the cork and brass pipe, an explosion will inevitably happen, which may be attended with danger, either from the bursting of the bottle or the thrusting out of the pipe. It is a good plan to fold a thick cloth several times round the bottle, then to place it in a box, so that the pipe may just project beyond the top; a lighted slip of paper may be applied to it at arm's length, and even if an explosion should happen, no damage can ensue. If the effervescence do not ensue very rapidly, more time must be allowed to elapse before the light is applied to the pipe; but the proportions of materials, stated at page 35, will generally evolve Hydrogen very rapidly, and three minutes will be sufficient; when the effervescence has nearly subsided, the small flame of hydrogen at the end of the pipe must be blown out, before removing the cork to throw away the residue of the operation.

Red Precipitate.—*Page* 67.

The Chemical name for this compound is Binoxide of Mercury, denoting that it contains two (Latin, *binus*) proportions of oxygen, and

ne of mercury; for there is another oxide of he metal, containing only one proportion of xygen and one of mercury, generally called he oxide.

For example, 8 parts by weight of oxygen, combine with 200 parts of mercury, to produce 208 of Oxide of mercury; but twice 8, or 16, parts by weight of oxygen combine with 200 parts of mercury to produce 216 of Binoxide of nercury.

This Binoxide of mercury must be purchased n the form of dark red crystals, and not in owder; a preparation called Nitrico-oxide of nercury is often sold in its stead; but this is erfectly unfit for the evolution of pure oxygen. Binoxide of mercury is poisonous; it is best preerved in a stoppered bottle.

LITMUS PAPER.—*Page* 76.

This useful test of the presence of common cids is made by pouring warm water into a cup ontaining half an ounce of a blue vegetable natter called Litmus (which may be purchased t a druggist's); the infusion thus obtained has dark blue colour; this may be diluted or ren-

happen to be damp from adventitious water, they must be dried, by spreading them on an earthenware plate, placed before the fire.

Chlorate of Potassa is a crystalline Anhydrous salt; but if damp, it must be treated as above.

There is no danger in drying these salts, or in reducing them separately to powder, but the greatest care must be taken that neither sulphur, charcoal, sulphuret of antimony nor phosphorus, accidentally mingle with Chlorate of potassa during the operation of powdering, because a violent and dangerous explosion would happen; the contact of sulphuric and muriatic acids with Chlorate of Potassa must likewise be avoided.

THE VOLTAIC TROUGH.—*Page* 169.

An Apparatus thus named in honour of Professor Volta.

A voltaic trough, containing twenty plates of four inches square, when charged with diluted sulphuric acid, is a very powerful instrument. The mode of proceeding is as follows: pour water into the cells of the trough until they are all filled within one quarter of an inch of their tops,

then empty the water into an earthenware basin, and gradually add sulphuric acid, (stirring the while with a stick,) until feeble effervescence is produced upon a bit of zinc thrown into the diluted acid.

By dipping a small earthenware jug into the diluted acid, it may then be poured into the cells of the trough until they are all filled as above.

Two pieces of thin copper bell-wire, about eighteen inches long, must have their ends brightened with emery paper; these are called conducting wires, and one is to be placed in the cell of the trough, on the right, and the other in that on the left hand of the operator, as shown in fig. 84.

The wetted fingers, simultaneously touching these conducting wires, will receive a slight shock, and this announces that Electricity is generated; the connexion may then be made with the platinum wires of the decomposing apparatus, merely by hooking them on.

When the experiment is concluded, and the acid emptied away, the trough should be well washed with water and allowed to drain; and if thus treated after each time of using, it will

remain a serviceable apparatus for many other experiments.

All the liquid agents above mentioned must be carefully placed in a box lined with sheet-lead, that in case of leakage, no damage may be done to the furniture of an apartment; the box must never be left accessible to any person, in the absence of its owner.

The results of all experiments, when useless, must be carefully thrown away, and the vessels which contained them well cleansed with water.

The face of the Chemical operator must never be held immediately over any vessels in which experiments are proceeding.

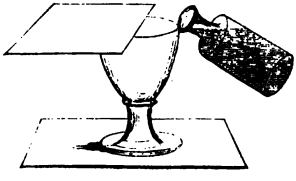
By attending to the foregoing instructions, the experiments may be performed with safety and success.

Fig. 1.

Fig. 4.

Fig. 2.

Fig. 3.



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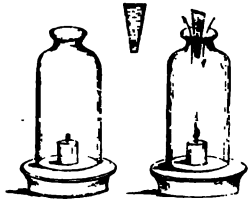
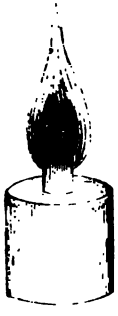


Fig. 10.

Fig. 13.



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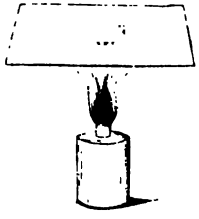

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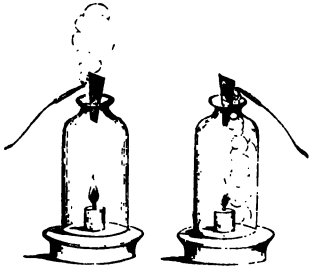

Fig. 12.

Fig. 15.

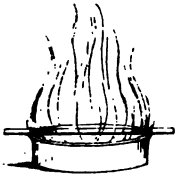

Fig. 16.

Fig. 19.

Fig. 20.

Fig. 17.

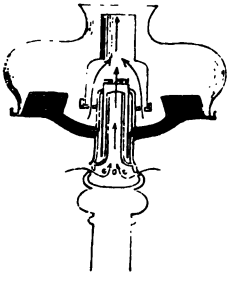

Fig. 18.

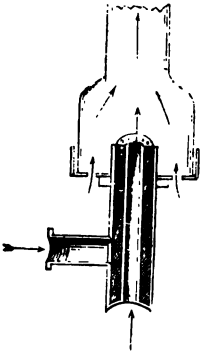

Fig. 30.

Fig. 31.

Fig. 32.

Fig. 33.

Fig. 34.

Fig. 35.

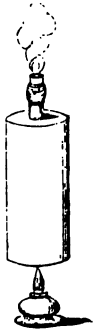

Fig. 36.

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Fig. 37.

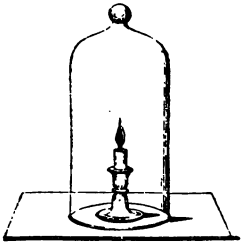
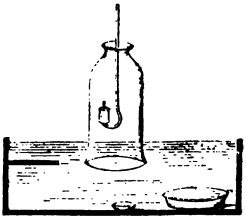


Fig. 41.

Fig. 39.



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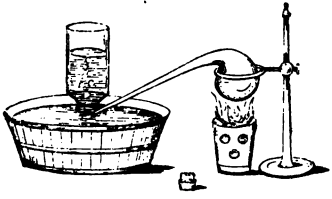

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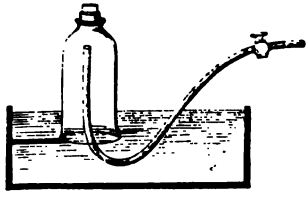
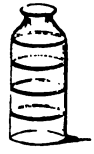


Fig. 43.

Fig. 44.



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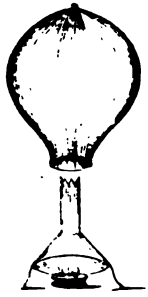

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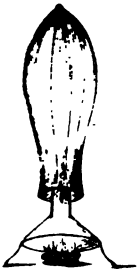

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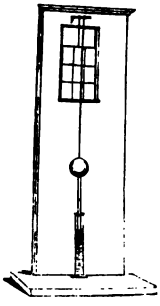

Fig. 46*a*.

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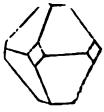

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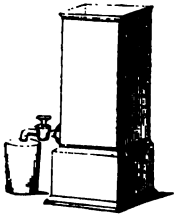

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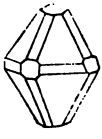

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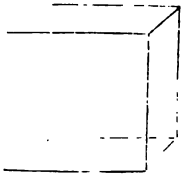

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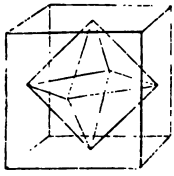

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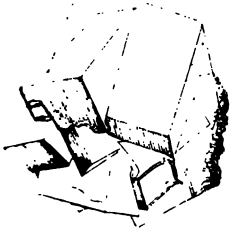

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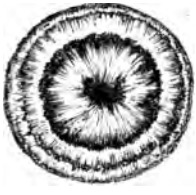

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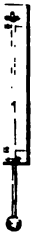

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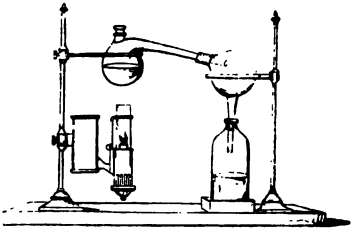

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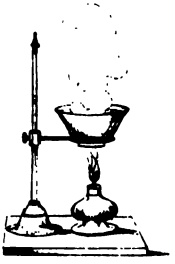

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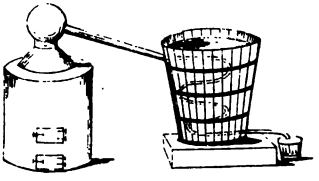

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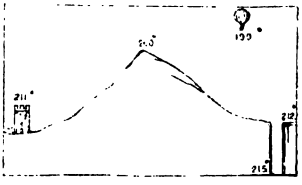

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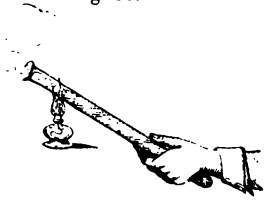

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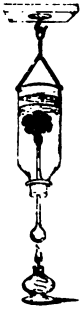

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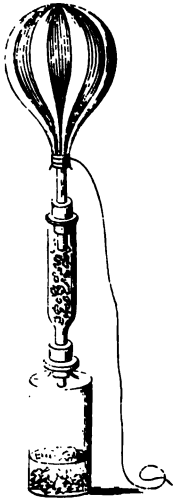

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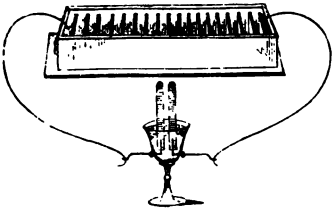

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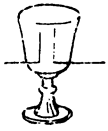

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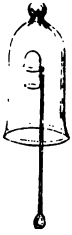

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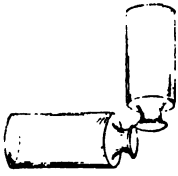

GLOSSARY.

ABSORPTION. (Latin, from *absorbeo*, to suck up.) The act or power of imbibing a fluid, either chemically or mechanically. Thus water absorbs carbonic acid, and sponge absorbs water.

ACICULAR. (Latin, from *acus*, a needle.) Resembling needles.

ADHESION. (Latin, from *ad*, to, and *hæreo*, to stick.) That force by which the particles of a substance cling to those of other substances.

AERIFORM. (Latin, from *aer*, the air, and *forma*, a form.) Possessing the form of air, *i.e.* a gas or vapour.

AFFINITY. (Latin, from *ad*, to, and *finis*, a boundary.) A force which disposes matter of opposite natures to unite and produce new matter.

AGGREGATION. (Latin, from *ad*, to, and *grex*, to collect.) The accumulation of particles in virtue of attraction of cohesion.

ALKALI. (Arabic.) A substance, generally speaking, more or less soluble in water, with a caustic taste, and gifted with the power of combining with an acid, so as to disguise its properties and form a neutral compound.

ANALYSIS. (Greek, from ἀνὰ, thoroughly, and λύω, to loosen.) The separation of a compound into its ultimate elements.

AQUEOUS. (Latin, from *aqua*, water.) Containing water; a liquid of which water forms a constituent.

ATTRACTION. (Latin, from *ad*, to, and *traho*, to draw.) The tendency which bodies have to approach each other and to unite either mechanically or chemically.

COHESION. (Latin, from *cum*, together, and *hæreo*, to stick.) That force by which the particles of a substance are held together.

COMBINATION. (Latin, from *cum*, with, and *binus*, two.) Union of bodies by means of chemical affinity.

COME OVER. The product of distillation is said to come over when it passes from the retort to the receiver.

CONDENSING, CONDENSATION. (Latin, *condensus*, to make thick.) Any matter urged into a smaller space than it before occupied, either by mechanical compression or chemical union; also the production of a liquid or solid from the cooling of its vapour.

CONDUCTION. (Latin, *cum*, together, and *duco*, to lead.) That which allows the passage of heat or electricity, either through its mass, or along its surface; metal, for example.

CRUCIBLE. (Latin, from *crucis*, a cross, because the alchymists impressed a cross upon the vessels in which they exposed metals to fusion, &c.) A vessel of any material capable of withstanding high heats, in which fusions of metals, &c., may be performed.

DECOMPOSITION. (Latin, *de*, negative, and *compositio*, in order.) The resolution of a compound into its proximate or ultimate elements.

DEFLAGRATION. (Latin, from *deflagro*, to burn.) Burning.

DEFLAGRATING SPOON. A small copper cup attached by means of a straight iron wire, so that it may be introduced into a bottle or jar of gas. See page [illegible].

DIFFUSED. (Latin, from *diffundo*, to pour out, spread.) Mechanically suspended or scattered throughout; thus mud is diffused throughout water, and dust throughout air.

DILUTED. (Latin, from *diluo*, to wash.) Weakened in activity by the addition of another, and comparatively inert, body; thus, sulphuric acid is diluted by mixing it with water; carbonic acid is diluted by mixing it with air.

EFFERVESCENCE. (Latin, from *ferveo*, to be hot, to rage.) The copious evolution of gaseous or aëriform matter from a liquid.

EFFLORESCENCE. (Latin, from *effloresco*, to blow as a flower.) When crystals part with their water of crystallization, or become dry by exposure to air, they are said to effloresce.

ELECTRICITY. (Greek, from ἤλεκτρον, amber.) The name of a power of matter which produces a variety of peculiar phenomena, the first of which were observed in the mineral substance called amber; the laws, hypotheses, and experiments, by which they are explained and illustrated, constitute the science of electricity.

ELECTROLYSIS. (Greek, from ἤλεκτρον, electricity, and λύω, to loosen.) The act of decomposing bodies by electricity, as water, at page 169.

FILTERING PAPER. (Italian, *feltro*, fulled wool, used as a strainer.) White unsized paper, or blotting paper.

FREEZING MIXTURE. A mixture of equal parts of common salt and pounded ice or snow, by which an intensely cold brine is produced, many degrees below the freezing point of water.

HERMETICALLY SEALED. A tube, or other vessel of glass, closed by heating it red hot, and then press-

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